

## POLISHING PAD WITH WINDOW FOR PLANARIZATION

### RELATED APPLICATIONS

**[0001]** This application is continuation-in-part of U.S. Patent Application Serial Number 10/664,951 filed on September 22, 2003, which claims the benefit of provisional patent application serial number 60/413,367 filed September 25, 2002.

### BACKGROUND OF THE INVENTION

**[0002]** 1. Field of the invention.

**[0003]** The present invention is directed to a polishing pad having a window that is constructed to be especially useful for chemical mechanical polishing or planarization of a microelectronic device, such as a semiconductor wafer. The window of the polishing pad is at least partially transparent and thus, can be particularly useful with polishing or planarizing tools that are equipped with through-the-platen wafer metrology.

**[0004]** 2. Background Information

**[0005]** In general, the polishing or planarization of a non-planar surface of a microelectronic device to an essentially planar surface involves rubbing the non-planar surface with the work surface of a polishing pad using a controlled and repetitive motion. A polishing slurry can be interposed between the rough surface of the article that is to be polished and the work surface of the polishing pad.

**[0006]** The fabrication of a microelectronic device such as a semiconductor wafer generally involves the formation of a plurality of integrated circuits on the wafer comprising, for example, silicon or gallium arsenide. The integrated circuits can be formed by a series of process steps in which patterned layers of materials, such as conductive, insulating and semiconducting materials, are formed on the substrate. In order to maximize the density of integrated circuits per wafer, it is desirable to have an essentially planar polished substrate at various stages throughout the semiconductor wafer production process. Thus, semiconductor wafer production can include at least one,

and more typically a plurality of polishing steps, which can use one or more polishing pads.

**[0007]** A chemical mechanical polishing (CMP) process can include placing the microelectronic substrate in contact with a polishing pad; rotating the pad while a force is applied to the backside of the microelectronic device; and applying an abrasive-containing chemically-reactive solution commonly referred to as a "slurry" to the pad during polishing. A CMP polishing slurry can contain an abrasive material, such as silica, alumina, ceria or mixtures thereof. The rotational movement of the pad relative to the substrate as slurry is provided to the device/pad interface can facilitate the polishing process. In general, polishing can be continued in this manner until the desired film thickness is removed.

**[0008]** Depending on the choice of polishing pad and abrasive, and other additives, the CMP process can provide effective polishing at desired polishing rates while reducing or minimizing surface imperfections, defects, corrosion, and erosion.

**[0009]** Polishing or planarization characteristics can vary from pad-to-pad, and throughout the operating lifetime of a given pad. Variations in the polishing characteristics of the pads can result in inadequately polished or planarized substrates which are not useful. Thus, it is desirable in the art to develop a polishing pad that exhibits reduced pad-to-pad variation in polishing or planarization characteristics. It is further desirable to develop a polishing pad that exhibits reduced variations in polishing or planarization characteristics throughout the operating life of the pad.

**[0010]** Planarizing tools having the ability to measure the progress of the planarization process while the wafer is held in the tool and in contact with the pad are known in the art. Measuring the progress of planarizing a microelectronic device during the planarizing process can be referred to in the art as "in-situ metrology". U.S. Pat. Nos. 5,964,643 and 6,159,073; and European Patent 1,108,501 describe polishing or planarizing tools and in-situ metrology systems. In general, in-situ metrology can include directing a beam of light through an at least partially transparent window located in the platen of the tool; the beam of light can be reflected off the surface of the wafer, back through the platen

window, and into a detector. The polishing pad can include a window that is at least partially transparent to the wavelengths used in the metrology system, and essentially aligned with the platen window.

**[0011]** One disadvantage with known pads having windows which are coplanar with the polishing surface, can include wearing of the window portion at a slower rate than the pad surface. A further disadvantage with known pads having a coplanar window can include scratching of the window as a result of its contact with abrasive particles in the slurry during the polishing or planarization process. A scratched window can generally reduce the transparency of the window and can cause an attenuation of the metrology signal.

**[0012]** Thus, it is desirable to develop a polishing pad that comprises a window area useful for in-situ metrology. It is further desirable that the window provides suitable transparency throughout the operating life of the pad.

## SUMMARY OF THE INVENTION

**[0013]** The present invention includes a polishing pad having a window. In a non-limiting embodiment, the polishing pad can comprise a first layer and a second layer. The first layer can function as the work surface or polishing layer of the pad. At least a portion of the second layer can comprise a window which is at least partially transparent to wavelengths used by the metrology instrumentation of polishing tools. Furthermore, the first layer can absorb at least 2 percent, or greater than 4 percent by weight of polishing slurry based on the total weight of the first layer.

**[0014]** The polishing pad of the present invention can comprise a first layer and a second layer. The first layer can function as the polishing or working surface of the pad such that the first layer can at least partially interact with the substrate to be polished and the polishing slurry. In a non-limiting embodiment, the first layer can be porous and permeable to polishing slurry. In a non-limiting embodiment, the second layer can be substantially nonporous and substantially impermeable to polishing slurry.

**[0015]** As used herein and the claims the term "substantially nonporous" means generally impervious to the passage of liquid, gas, and bacteria. On a macroscopic scale, a substantially nonporous material exhibits few if any pores. As used herein and the claims, the term "porous" means having pore(s) and the term "pore(s)" refers to minute opening(s) through which matter passes.

**[0016]** It is noted that, as used in this specification, the singular forms "a," "an," and "the" include plural referents unless expressly and unequivocally limited to one referent.

**[0017]** For the purposes of this specification, unless otherwise indicated, all numbers expressing quantities of ingredients, reaction conditions, and so forth used in the specification and claims are to be understood as being modified in all instances by the term "about." Accordingly, unless indicated to the contrary, the numerical parameters set forth in the following specification and attached claims are approximations that may vary depending upon the desired properties sought to be obtained by the present invention. At the very least, and not as an attempt to limit the application of the doctrine of equivalents to the scope of the claims, each numerical parameter should at least be construed in light of the number of reported significant digits and by applying ordinary rounding techniques.

**[0018]** Notwithstanding that the numerical ranges and parameters setting forth the broad scope of the invention are approximations, the numerical values set forth in the specific examples are reported as precisely as possible. Any numerical value, however, inherently contain certain errors necessarily resulting from the standard deviation found in their respective testing measurements.

**[0019]** It is noted that, as used in this specification, the singular forms "a," "an," and "the" include plural referents unless expressly and unequivocally limited to one referent. Numerical ranges are intended to include all subsets within that range whether expressly further defined or not.

**[0020]** The present invention will be described in detail in the description of the preferred embodiments taken together with the drawings in which like reference

numerals represent like elements throughout. The drawings are illustrative of the present invention, but are not intended to be restrictive thereof.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0021]** Figure 1 is a schematic side elevation view of a stacked polishing pad with window on a rotary platen in accordance with one aspect of the present invention;

**[0022]** Figure 2 is a schematic top plan view of the stacked polishing pad on a rotary platen in accordance with figure 1;

**[0023]** Figure 3 is a schematic side elevation view of a stacked polishing pad with a window on a rotary platen in accordance with one aspect of the present invention;

**[0024]** Figure 4 is a schematic side elevation view of looped belt polishing pad with a window in accordance with one aspect of the present invention; and

**[0025]** Figure 5 is a schematic side elevation view of indexing belt polishing pad with a window in accordance with one aspect of the present invention.

## DESCRIPTION OF THE PREFERRED EMBODIMENTS

**[0026]** The present invention is directed to a polishing pad 10 for use in polishing a microelectronic substrate. Various pad constructions 10 suitable for use in the present invention are known in the art, representative examples of which are shown in figures 1-5 and described below. In particular, the polishing pad 10 of the present invention can include a window 32. The polishing pad 10 of the present invention can be useful for polishing articles and can be especially useful for chemical mechanical polishing or planarization of a microelectronic device, such as a semiconductor wafer. The window 32 of the polishing pad 10 is at least partially transparent and thus, can be particularly useful with polishing or planarizing tools (platen 24) that are equipped with through-the-platen wafer metrology (schematically represented at 34).

**[0027]** The polishing pad 10 can include a polishing or first layer 12 and a sublayer 14. The polishing layer 12 can be at least partially connected to the sublayer 14 through a

covered surface 20 of the sublayer 14 through a second layer 26, with the sublayer 14 having an outer peripheral or exposed edge 16. The sublayer 14 can have an outer peripheral edge 16. In one embodiment in which the first layer 12 is smaller than the second and third layers 26 and 14, the outer peripheral edge includes a radial surface 16A and an annular surface 16B.

**[0028]** The first layer 12 can include a variety of materials known in the art. Non-limiting examples of suitable materials comprising the first layer 12 can include but are not limited to particulate polymer and crosslinked polymer binder as described in U.S. Pat. No. 6,477,926B1; particulate polymer and an organic polymer binder as described in U.S. patent application Ser. No. 10/317,982 that published as publication number 2003-0217517; sintered particles of thermoplastic resin as described in U.S. Pat. Nos. 6,062,968; 6,117,000; and 6,126,532; and pressure sintered powder compacts of thermoplastic polymer as described in U.S. Pat. Nos. 6,231,434B1; 6,325,703B2; 6,106,754; and 6,017,265. Further non-limiting examples of suitable materials comprising the first layer can include polymeric matrices impregnated with a plurality of polymeric microelements, wherein each polymeric microelement can have a void space therein, as described in U.S. Pat. Nos. 5,900,164 and 5,578,362.

**[0029]** The thickness of the first layer 12 can vary. In alternate non-limiting embodiments, the first layer can have a thickness of at least 0.020 inches, or at least 0.040 inches; or 0.150 inches or less, or 0.080 inches or less.

**[0030]** In another non-limiting embodiment, the first layer 12 can include pores such that polishing slurry can be at least partially absorbed by the first layer 12. The number of pores can vary. In alternate non-limiting embodiments, the first layer 12 can have a porosity, expressed as percent pore volume, of at least 2 percent by volume based on the total volume of the first layer, or 50 percent or less by volume based on the total volume of the first layer, or from 2 to 50 percent by volume based on the total volume of the first layer, or from 5 to 45 percent by volume based on the total volume of the first layer, or from 10 to 40 percent by volume based on the total volume of the first layer, or from 15

to 35 percent by volume based on the total volume of the first layer. [0031] The percent pore volume of the polishing pad layer can be determined using a variety of techniques known in the art. In a non-limiting embodiment, the following expression can be used to calculate percent pore volume:

$$100 \times (\text{density of the pad}) \times (\text{pore volume of the pad}).$$

[0032] The density can be expressed in units of grams per cubic centimeter, and can be determined by a variety of conventional methods known in the art. In a non-limiting embodiment, the density can be determined in accordance with ASTM D 1622-88. The pore volume can be expressed in units of cubic centimeters per gram, and can be determined using conventional methods and equipment known in the art. In a non-limiting embodiment, pore volume can be measured in accordance with the mercury porosimetry method in ASTM D 4284-88, using an Autopore III mercury porosimeter from Micromeritics can be used. In a further non-limiting embodiment, the pore volume measurements can be made under the following conditions: a contact angle of 140°; a mercury surface tension of 480 dynes/cm; and degassing of the polishing pad layer sample under a vacuum of 50 micrometers of mercury.

[0033] In a non-limiting embodiment, the first layer 12 can have an at least partially open structure such that it can absorb slurry. In alternate non-limiting embodiments, the first layer can absorb at least 2 percent by weight of polishing slurry based on the total weight of the first layer, or not more than 50 percent by weight, or from 2 percent by weight to 50 percent by weight, or from greater than 4 percent by weight to 50 percent by weight, or from 5 percent by weight to 45 percent by weight, or from 6 percent by weight to 40 percent by weight, or from 10 percent by weight to 25 percent by weight.

[0034] In another non-limiting embodiment of the present invention, the first layer 12 of the polishing pad 10 can have a compressibility greater than the second layer 26. As used herein, the term "compressibility" refers to the percent volume compressibility measurement. In a further non-limiting embodiment, the percent volume compressibility of the first layer 12 can be at least 0.3 percent; or 3 percent or less; or from 0.3 to 3 percent; when a load of 20 psi is applied.

**[0035]** The percent volume compressibility of a pad 10 layer (12, 14 or 26) can be determined using various methods known in the art. In a non-limiting embodiment, the percent volume compressibility of a pad 10 layer (12, 14 or 26) can be determined using the following expression.

$$100 \times (\text{pad volume without load} - \text{pad volume under load}) / (\text{pad volume without load})$$

**[0036]** In a non-limiting embodiment, the area of the pad 10 layer (12, 14 or 26) does not change when the load is placed on it; thus, the preceding equation for volume compressibility can be expressed in terms of pad layer thickness by the following expression.

$$100 \times (\text{pad layer thickness without load} - \text{pad layer thickness under load}) / (\text{pad layer thickness without load})$$

**[0037]** The pad layer thickness can be determined using a variety of known methods. In a non-limiting embodiment, the pad layer thickness can be determined by placing a load (such as, but not limited to, calibrated weights) on the pad layer 12, 14 or 26 sample and measuring the change in thickness of the pad layer 12, 14 or 26 as a result of the load. In a further non-limiting embodiment, a Mitutoyo Electronic Indicator, Model ID-C112EB can be used. The indicator has a spindle or threaded rod which can be fitted at one end with a flat contact under which the pad layer 12, 14 or 26 is placed. The spindle can be fitted at the other end with a device for applying specified loads to the contact area, such as but not limited to a balance pan which accepts calibrated weights. The Indicator displays the displacement of the pad layer 12, 14 or 26 resulting from applying the load. The Indicator display is typically representative of inches or millimeters. The Electronic Indicator can be mounted on a stand, such as a Mitutoyo Precision Granite Stand, to provide stability while taking the measurements. The lateral dimensions of the pad layer 12, 14 or 26 can be sufficient to permit measurements at least 0.5" from any edge. The surface of the pad layer 12, 14 or 26 can be flat and parallel over a sufficient area to permit uniform contact between the test pad layer 12, 14 or 26 and the flat contact. The pad layer 12, 14 or 26 to be tested can be placed under the flat contact. The thickness of the pad layer 12, 14 or 26 can be measured prior to applying the load. Calibrated balance



weights can be added to the balance pan for a specific resultant load. The pad layer 12, 14 or 26 then can be compressed under the specified load. The Indicator can display the thickness/height of the pad layer 12, 14 or 26 under the specified load. The thickness of the pad layer 12, 14 or 26 prior to applying the load minus the thickness of the pad layer 12, 14 or 26 under the specified load can be used to determine the displacement of the pad layer 12, 14 or 26. In a non-limiting embodiment, a load of 20 psi can be applied to the pad layer 12, 14 or 26. Measurements can be made at a standardized temperature such as room temperature. In a non-limiting embodiment, measurements can be taken at a temperature of 22° C+/-2° C.

**[0038]** In alternate non-limiting embodiments, the above-described method of measuring pad layer thickness can be applicable to a stacked pad 10 assembly or layer(s) 12, 14 or 26 comprising the stacked pad 10 assembly.

**[0039]** In a non-limiting embodiment, a procedure for measuring percent volume compressibility can include placing the contact on the granite base and adjusting the indicator to read zero. The contact can then be raised and the specimen (such as pad layer 12, 14 or 26) placed on the granite stand under the contact with the edge of the contact at least 0.5" from any edge of the specimen. The contact can be lowered onto the specimen and the specimen thickness measurement can be taken after 5+/-1 seconds. Without moving the specimen or the contact, sufficient weight can be added to the pan to cause a force of 20 psi to be applied to the specimen by the contact. The reading for the specimen thickness under load measurement can be made after 15+/-1 seconds. The measurement procedure can be repeated, making five measurements at different positions on the specimen at least 0.25" apart using 20 psi of compressive force.

**[0040]** In a non-limiting embodiment, the softness of the first layer 12 can be determined. As used herein and the claims, the term "softness" refers to the Shore A Hardness of the material. In general, the softer the material, the lower the Shore A Hardness value. In alternate non-limiting embodiments, the first layer 12 can have a Shore A Hardness of at least 85; or 99 or less, or from 85 to 99. The Shore A Hardness value can be determined using various methods and equipment known in the art. In a non-limiting embodiment,

Shore A Hardness can be determined in accordance with the procedure recited in ASTM D 2240, using a Shore "Type A" Durometer having a maximum indicator (available from PCT Instruments, Los Angeles, Calif.). In a non-limiting embodiment, the test method for Shore A Hardness can include the penetration of a specific type of indenter being substantially forced into the test material under specified conditions. In this embodiment, the Shore A Hardness can be inversely related to the penetration depth and can be dependent on the elastic modulus and viscoelastic behavior of the test material.

**[0041]** In a non-limiting embodiment, the first layer 12 can comprise grooves 19 or pattern on the work or polishing surface 18. The types of grooves 19 and/or patterns can vary and can include the various types of grooves 19 and/or patterns known in the art. The process for making the grooves 19 and patterns can also vary and can include the various conventional methods known in the art.

**[0042]** The polishing pad 10 of the present invention further comprises a second layer 26. In a non-limiting embodiment, the second layer 26 can be connected to at least a portion of the first layer 12. In a further non-limiting embodiment, the first layer 12 can be connected to at least a portion of the second layer 26, and the second layer 26 can be connected to at least a portion of an optional third or sublayer 14.

**[0043]** The second layer 26 can include a variety of materials known in the art. The second layer 26 can be selected from substantially non-volume compressible polymers and metallic films and foils. As used herein and the claims, "substantially non-volume compressible" means that the volume can be reduced by less than 1% when a load of 20 psi is applied. In a non-limiting embodiment, the method for applying the load and measuring the reduction in volume is previously described herein can be employed.

**[0044]** Non-limiting examples of substantially non-volume compressible polymers can include polyolefins, such as but not limited to low density polyethylene, high density polyethylene ultra-high molecular weight polyethylene and polypropylene; polyvinylchloride; cellulose-based polymers, such as but not limited to cellulose acetate and cellulose butyrate; acrylics; polyesters and co-polyesters, such as but not limited to PET and PETG; polycarbonate; polyamides, such as but not limited to nylon 6/6 and

nylon 6/12; and high performance plastics, such as but not limited to polyetheretherketone, polyphenylene oxide, polysulfone, polyimide, and polyetherimide; and mixtures thereof.

**[0045]** Non-limiting examples of metallic films can include but are not limited to aluminum, copper, brass, nickel, stainless steel, and combinations thereof.

**[0046]** The thickness of the second layer 26 can vary. In alternate non-limiting embodiments, the second layer 26 can have a thickness of at least 0.0005, or at least 0.0010; or 0.0650 inches or less, or 0.0030 inches or less.

**[0047]** In a non-limiting embodiment, the second layer 26 can be flexible to enhance or increase the uniformity of contact between the polishing pad 10 and the surface of the substrate being polished. A consideration in selecting the material for the second layer 26 can be the capability of a material to provide compliant support to the work surface 18 of the polishing pad 10 such that the first layer 12 substantially conforms to the macroscopic contour or long-term surface of the device being polished. A material having said capability can be desirable for use as the second layer 26 in the present invention.

**[0048]** The flexibility of the second layer 26 can vary. The flexibility can be determined using a variety of conventional techniques known in the art. As used herein and the claims the term "flexibility" (F) refers to the inverse relationship of second layer thickness cubed ( $t^3$ ) and the flexural modulus of the second layer material (E), i.e.  $F=1/(t^3XE)$ . In alternate non-limiting embodiments, the flexibility of the second layer can be at least  $0.5 \text{ in}^{-1} \text{ lb}^{-1}$ ; or at least  $100 \text{ in}^{-1} \text{ lb}^{-1}$ ; or from  $1 \text{ in}^{-1} \text{ lb}^{-1}$  to  $100 \text{ in}^{-1} \text{ lb}^{-1}$ .

**[0049]** In a non-limiting embodiment, the second layer 26 can have a compressibility which allows the polishing pad 10 to substantially conform to the surface of the article to be polished. The surface of a microelectronic substrate, such as a semiconductor wafer, can have a "wave" contour as a result of the manufacturing process. It is contemplated that if the polishing pad 10 cannot adequately conform to the "wave" contour of the substrate surface, the uniformity of the polishing performance can be degraded. For example, if the pad 10 substantially conforms the ends of the "wave", but cannot

substantially conform and contact the middle portion of the "wave", only the ends of the "wave" can be polished or planarized and the middle portion can remain substantially unpolished or unplanarized.

**[0050]** The compressibility of the second layer 26 can vary. As previously described, the term "compressibility" refers to the percent volume compressibility measurement. In alternate non-limiting embodiments, the percent volume compressibility of the second layer 26 can be at least one percent; or three percent or less; or from one to three percent.

**[0051]** The percent volume compressibility can be determined using a variety of conventional methods known in the art. In a non-limiting embodiment, the percent volume compressibility is determined as previously described herein.

**[0052]** In another non-limiting embodiment, the second layer 26 can distribute the compressive forces experienced by the first layer 12 over a larger area of an optional third layer 14. In a non-limiting embodiment, the second layer 26 is substantially non-volume compressible.

**[0053]** In another non-limiting embodiment, the second layer 26 can function as a substantial barrier to fluid transport between the first layer 12 and an optional third layer 14 at least partially connected to the second layer 26. Thus, a consideration in selecting the material comprising the second layer 26 can be the ability of the material to substantially reduce, minimize or essentially prevent the transport of polishing slurry from the first layer 12 to an optional third layer 14. In a non-limiting embodiment, the second layer 26 can be substantially impermeable to the polishing slurry such that the optional third layer 14 does not become saturated with polishing slurry.

**[0054]** In an alternate non-limiting embodiment, the second layer 26 can be perforated (not shown) such that polishing slurry can penetrate the first 12 and second 26 layers to wet an optional third layer 14. In a further non-limiting embodiment, the optional third layer 14 can be substantially saturated with polishing slurry. The perforations in the second layer 26 can be formed by a variety of techniques known to the skilled artisan, such as but not limited to punching, die cutting, laser cutting or water jet cutting. The

hole size, number and configuration of the perforations can vary. In a non-limiting embodiment, the perforation hole diameter can be at least (1/16) inch with at least 26 holes per square inch in a staggered hole pattern.

**[0055]** In a non-limiting embodiment, the first layer 12 can be connected to at least a portion of the second layer 26 to produce a stacked pad 10 assembly. As used herein and the claims, the term "connected to" means to link together or place in relationship either directly, or indirectly by one or more intervening materials. In a non-limiting embodiment, the first and second layers 12 and 26 are at least partially connected such that the opening of the first layer 28 can be at least partially aligned with the at least partially transparent window 32 of the second layer 26.

**[0056]** In a non-limiting embodiment, the first layer 12 of the polishing pad 10 can be connected to at least a portion of the second layer 26 using an adhesive. A suitable adhesive for use in the present invention can provide sufficient peel resistance such that the pad layers (12, 14 and 26) essentially remain in place during use. Further, the adhesive can be selected to sufficiently withstand shear stresses which are present during the polishing or planarization process and moreover, can sufficiently resist chemical and moisture degradation during use. The adhesive can be applied using conventional techniques known to the skilled artisan. In a non-limiting embodiment, the adhesive can be applied to a lower surface of the first layer 12 and/or an upper surface of the second layer 26 which are parallel facing to one another.

**[0057]** The adhesive can be chosen from a wide variety of adhesive materials known in the art, such as but not limited to contact adhesives, pressure sensitive adhesives, structural adhesives, hot melt adhesives, thermoplastic adhesives, and curable adhesives, such as thermosetting adhesives. Non-limiting examples of structural adhesives can be chosen from polyurethane adhesives, and epoxy resin adhesives; such as those based on the diglycidyl ether of bisphenol A. Non-limiting examples of pressure sensitive adhesives can include an elastomeric polymer and a tackifying resin.

**[0058]** The elastomeric polymer can be chosen from natural rubber, butyl rubber, chlorinated rubber, polyisobutylene, poly(vinyl alkyl ethers), alkyd adhesives, acrylics

such as those based on copolymers of 2-ethylhexyl acrylate and acrylic acid, block copolymers such as styrene-butadiene-styrene, and mixtures thereof. In a non-limiting embodiment, a pressure sensitive adhesive can be applied to a substrate using an organic solvent such as toluene or hexane, or from a water-based emulsion or from a melt. As used herein, "hot melt adhesive" refers to an adhesive comprised of a nonvolatile thermoplastic material that can be heated to a melt, then applied to a substrate as a liquid. Non-limiting examples of hot melt adhesives can be chosen from ethylene-vinyl acetate copolymers, styrene-butadiene copolymers, ethylene-ethyl acrylate copolymers, polyesters, polyamides such as those formed from the reaction of a diamine and a dimer acid, and polyurethanes.

**[0059]** In a non-limiting embodiment of the present invention, the first layer 12 can comprise an opening 28. In a further non-limiting embodiment, at least a portion of the second layer 26 can comprise a window 32 which is at least partially transparent to wavelengths used by the metrology instrumentation of the planarizing equipment 34. The size, shape, and positioning of the opening 28 in the first layer 12 and/or the window 32 in the second layer 26 can be dependent upon the metrology instrumentation 34 and polishing apparatus (such as platen 24) being employed to polish and/or planarize the pad. The opening 28 can be produced by a variety of conventional methods known in the art. In alternate non-limiting embodiments, the opening 28 can be made by punching, die cutting, laser cutting or water jet cutting. In a further non-limiting embodiment, the opening 28 can be formed by molding the first layer 12. In an alternate non-limiting embodiment, the opening 28 can be die cut into the first layer 12 using an NAEF Model B die press fitted with dies of suitable size and shape, which are commercially available from MS Instruments Company, Stony Brook, N.Y.

**[0060]** In a non-limiting embodiment, the opening 28 in the first layer 12 can be produced prior to stacking together and/or at least partially connecting the first layer 12 with the second layer 26.

**[0061]** At least a portion of the second layer 26 can comprise an at least partially transparent window 32. In a non-limiting embodiment, the second layer 26 can comprise

an at least partially transparent material. In another non-limiting embodiment, the second layer 26 can comprise a substantially non-transparent material; an opening can be cut into the second layer 26 to remove a portion of the second layer 26; an at least partially transparent material can be inserted into the opening in the second layer 26 forming partially transparent window 32. The opening in the second layer 26 can be made using a variety of methods previously described herein. In a non-limiting example, the second layer 26 can include a metal foil; an opening can be cut into the metal foil to remove a portion of the metal foil; a piece of polyester can be cut into a size and shape that substantially corresponds to the opening; the polyester can be fitted into the opening in the metal foil to form an at least partially transparent window 32.

**[0062]** In a non-limiting embodiment, the second layer 26 can comprise an adhesive assembly. The adhesive assembly can include interposing the second layer 26 between an upper adhesive layer and a lower adhesive layer. In a non-limiting embodiment, the upper adhesive layer of the adhesive assembly can be at least partially connected to the lower surface of the first layer 12. The lower adhesive layer of the adhesive assembly can be at least partially connected to the upper surface of an optional third layer 14. The second layer of the adhesive assembly can be selected from the aforementioned suitable materials for the second layer 26 of the polishing pad 10. The upper and lower adhesive layers of the adhesive assembly can be selected from the non-limiting examples of adhesives previously mentioned herein. In a non-limiting embodiment, the upper and lower adhesive layers each can be contact adhesives. The adhesive assembly can be referred to in the art as two-sided or double coated tape. Non-limiting examples of commercially available adhesive assemblies include those from 3M, Industrial Tape and Specialties Division.

**[0063]** In a further non-limiting embodiment, at least a portion of the adhesive layer can be removed from the second layer of the adhesive assembly exposing at least a portion of the at least partially transparent middle layer of the adhesive assembly, thereby forming an at least partially transparent window 32 in the second layer 26. In alternate non-limiting embodiments, the removal of the adhesive can be performed prior to stacking the layers (12, 26 and optionally 14) or after the layers (12, 26 and optionally 14) are stacked.

The removal process can include a variety of methods known to the skilled artisan, including but not limited to dissolution of the adhesive in solvent or aqueous detergent solution, or physically stripping the adhesive from the second layer. In a non-limiting embodiment, physically stripping the adhesive can be include contacting the adhesive with a material to which the adhesive substantially adheres, and then pulling the material from the second layer 26, whereby the adhesive is removed with the material.

**[0064]** In a further non-limiting embodiment, the window 32 of the second layer 26 can be recessed below the polishing surface 18 of the pad 10 by a distance equal to the thickness of the first layer 12 of the pad 10.

**[0065]** In another non-limiting embodiment, the pad 10 assembly can include a coating on at least a portion of the top and/or bottom sides of the window 32 of the second layer 26. The coating can be at least partially applied with an adhesive in place or following removal of the adhesive. The coating can be at least partially applied prior to stacking the layers (12, 26 and optionally 14) or after the layers (12, 26 and optionally 14) have been stacked. The coating can provide any one of the following properties, for example: improved transparency of the window 32 area, improved abrasion resistance, improved puncture resistance. In a non-limiting embodiment, the coating can include a resin film, or a cast-in-place resin coating.

**[0066]** Non-limiting examples of suitable resin films for use in the present invention can include the materials described above for the second layer 26. In alternative non-limiting embodiments, the resin film chosen for the coating can be the same material or different material as that comprising the second pad layer 26. The resin film can be at least partially adhered to the window area 32 of the second layer 26 by any means known to the skilled artisan, such as the adhesive methods and materials listed above for pad 10 stack adhesives. In a non-limiting embodiment, the coating can be a layer of resin film that can be the same as the material used for the second layer 26. The coating can be at least partially applied after assembly of the pad 10 stack. The coating can be at least partially applied to both the top and bottom surfaces of the window area 32 of the second



layer 26, and the adhesive can be at least partially adhered using a contact adhesive used as the stack adhesive.

**[0067]** In a non-limiting embodiment, the coating can be a cast-in-place resin coating, which can be applied as a liquid, as a solvent solution, dispersion, or aqueous latex; as a melt, or as a blend of resin precursors that can react to form the coating. The application of the liquid can be accomplished by a variety of known methods, including spraying, padding, and pouring. Non-limiting examples of suitable materials for the coating include thermoplastic acrylic resins, thermoset acrylic resins, such as hydroxyl-functional acrylic latexes crosslinked with urea-formaldehyde or melamine-formaldehyde resins, hydroxyl-functional acrylic resins crosslinked with epoxy resins, or carboxyfunctional acrylic latexes crosslinked with carbodiimides or polyimines or epoxy resins; urethane systems, such as hydroxyfunctional acrylic resin crosslinked with polyisocyanate, moisture-cured isocyanate-terminated resins; carbamate-functional acrylic resins crosslinked with melamine-formaldehyde resins; epoxy resins, such as polyamide resin crosslinked with bisphenol A epoxy resins, phenolic resins crosslinked with bisphenol A epoxy resins; polyester resins, such as hydroxyl-terminated polyesters crosslinked with melamine-formaldehyde resins or with polyisocyanates or with epoxy crosslinkers.

**[0068]** In a non-limiting embodiment, the coating can be an aqueous acrylic latex, which can be applied following stacking of the pad 10 assembly. The coating can be at least partially applied to the top and bottom surfaces of the window area 32 of the second layer 26. Application of the coating can be performed following removal of an adhesive from the window area 32.

**[0069]** The window pad 10 of the present invention can be used with a variety of polishing equipment known in the art. In a non-limiting embodiment, a Mirra polisher, produced by Applied Materials Inc, Santa Clara Calif., can be used wherein the shape of the opening 28 (and opening 30 in optional sublayer 14) is a rectangle, having a size 0.5" X 2", being positioned with the long axis radially oriented and centered 4" from the center of the pad 10. The platen 24 for the Mirra polisher is 20" in diameter. A pad 10 for

use with this polisher including platen 24 can comprise a circle of a 20-inch diameter having a window 32 located in the area as described.

**[0070]** In a further non-limiting embodiment, a Teres polisher commercially available from Lam Research Corporation, Fremont, Calif., can be employed. This polisher, represented by rollers 24' in figure 4, uses a continuous belt instead of a circular platen. The pad 10 for this polisher can be a continuous belt of 12" width and 93.25" circumference, which has a window area 32 suitably sized and positioned to align with the metrology window (34) of the Teres polisher can be such that it can be at least partially aligned with the at least partially transparent window 32 in the second layer 26 and the aligned openings 28 and 30 of the first and optional third layers 12 and 14. In a further non-limiting embodiment, an indexing belt polisher can be employed. This polisher, represented by rollers 24" in figure 5, uses an indexing belt instead of a circular pad or continuous belt of earlier designs. In this type of polisher the pad 10 includes a plurality of windows 32 at each indexing position of the pad 10 wherein each indexed position will align a window 32 with the metrology window 34.

**[0071]** As identified previously herein, the polishing pad 10 of the present invention can comprise additional optional layer(s) such as 14. The additional layer(s) 14 can contain opening(s) 30 that are substantially aligned with the opening 28 in the first layer 12 and the at least partially transparent window 32 in the second layer 26.

**[0072]** In a non-limiting embodiment, the polishing pad 10 of the present invention can comprise a third layer 14. The third layer 14 can function as the bottom layer 14 of the pad 10 which can be attached to the platen 24 of the polishing apparatus (or engage rolls 24' or 24'' of the polishing equipment depending of the polishing equipment).

**[0073]** In a non-limiting embodiment, the third layer 14 can comprise a material that is softer than the first layer 12. As used herein, the term "softness" refers to the Shore A Hardness of the material. The softer the material, the lower the Shore A Hardness value. Thus, in the present invention, the Shore A Hardness value of the third layer 14 can be lower than the Shore A Hardness value of the first layer 12. In a non-limiting embodiment, the third layer 14 can have a Shore A Hardness of at least 15. In alternate

non-limiting embodiments, the Shore A Hardness of the third layer 14 can be at least 45, or 75 or less, or from 45 to 75. The Shore A Hardness can be determined using a variety of conventional methods known in the art. In a non-limiting embodiment, the Shore A Hardness can be determined as previously described herein.

**[0074]** In a non-limiting embodiment, the third layer 14 can be used to increase the uniformity of contact between the polishing pad 10 and the surface of the substrate undergoing polishing.

**[0075]** In a non-limiting embodiment of the present invention, the material comprising the third layer 14 of the polishing pad 10 can have a compressibility greater than the material comprising the first layer 12. As previously described, the term "compressibility" refers to the percent volume compressibility measurement. Thus, the percent volume compressibility of the third layer 14 is greater than the percent volume compressibility of the first layer 12. In a non-limiting embodiment, the percent volume compressibility of the third layer 14 can be less than 20 percent when a load of 20 psi is applied. In alternate non-limiting embodiments, the percent volume compressibility of the third layer 14 can be less than 10 percent when a load of 20 psi is applied, or less than 5 percent when a load of 20 psi is applied. As previously identified percent volume compressibility can be determined by a variety of conventional methods known in the art. In a non-limiting embodiment, percent volume compressibility can be determined as previously described herein.

**[0076]** The thickness of the third layer 14 can vary. In general, the third layer 14 thickness should be such that the pad 10 is not too thick. A pad 10 which is too thick can be difficult to place on and take off of the planarization equipment (24). Thus, in alternate non-limiting embodiments, the thickness of the third layer 14 can be at least 0.040 inches, or at least 0.045 inches; or 0.100 inches or less, or 0.080 inches or less, or 0.065 inches or less.

**[0077]** The sublayer or third layer 14 can comprise a wide variety of materials known in the art. Suitable materials can include natural rubber, synthetic rubbers, thermoplastic elastomer, foam sheet and combinations thereof. The material of the sublayer can be

foamed or blown to produce a porous structure. The porous structure can be open cell, closed cell, or combinations thereof. Non-limiting examples of synthetic rubbers can include neoprene rubber, silicone rubber, chloroprene rubber, ethylene-propylene rubber, butyl rubber, polybutadiene rubber, polyisoprene rubber, EPDM polymers, styrene-butadiene copolymers, copolymers of ethylene and ethyl vinyl acetate, neoprene/vinyl nitrile rubber, neoprene/EPDM/SBR rubber, and combinations thereof. Non-limiting examples of thermoplastic elastomers can include polyolefins, polyesters, polyamides, polyurethanes such as those based on polyethers and polyesters, and copolymers thereof. Non-limiting examples of foam sheet can include ethylene vinyl acetate sheets and polyethylene foam sheets, such as but not limited to those which are commercially available from Sentinel Products, Hyannis, N.J.; polyurethane foam sheets, such as but not limited to those which are commercially available from Illbruck, Inc., Minneapolis, Minn.; and polyurethane foam sheets, and polyolefin foam sheets, such as but not limited to those which are available from Rogers Corporation, Woodstock, Conn. In a further non-limiting embodiment, the sublayer 14 can include non-woven or woven fiber mat, and combinations thereof; such as but not limited to polyolefin, polyester, polyamide, or acrylic fibers, which have been impregnated with a resin. The fibers can be staple or substantially continuous in the fiber mat. Non-limiting examples can include but are not limited to non-woven fabric impregnated with polyurethane as describe in U.S. Pat. No. 4,728,552, such as polyurethane impregnated felt. A non-limiting example of a commercially available non-woven subpad can be Suba™ IV, from Rodel, Inc. Newark Del.

**[0078]** In the present invention, the optional third layer 14 can comprise an opening 30. In alternate non-limiting embodiments, the opening 30 in the optional third layer 14 can be produced by any suitable means known in the art, such as those previously identified relative to the opening 28 in the first layer 12. Further, as previously identified, the size, shape and position of the opening 30 can be dependent upon the metrology instrumentation and polishing apparatus employed.

**[0079]** In a non-limiting embodiment, the third layer 14 can be at least partially connected to the second layer 26 and can be in contact with the base or platen 24 of the

planarizing machine. The third layer 14 can contain an opening 30 that is at least partially aligned with the opening 28 of the first layer 12 and the at least partially transparent or window area 32 of the second layer 26.

**[0080]** In an alternate non-limiting embodiment, the first layer 12 of the polishing pad 10 can be connected to at least a portion of the second layer 26 and the second layer 26 can be connected to at least a portion of a third layer 14 using an adhesive. Suitable adhesives can include those previously recited herein.

**[0081]** In a further non-limiting embodiment, the polishing pad 10 of the present invention can comprise a first layer 12, a second layer 26, and a third layer 14. The first and third layers 12 and 14 each comprise an opening 28 and 30. The openings 28 and 30 of the first and third layers 12 and 14 can be at least partially aligned with one another. At least a portion of the second layer 26 can include an at least partially transparent window 32. The window 32 can be at least partially coated on both sides with contact adhesive, and the layers 12, 14 and 26 can be pressed together to form a stacked pad 10 assembly. The adhesive can then be physically stripped from the top and bottom surface of the window area 32 of the second layer 26 using a material to which the adhesive substantially adheres. A non-limiting example of a material to which the adhesive substantially adheres is Teslin® SP-1000, a synthetic sheet material which is commercially available from PPG Industries, Inc, Pittsburgh, Pa.

**[0082]** The polishing pads 10 of the present invention can be used in combination with polishing slurries, such as polishing slurries, which are known in the art. Non-limiting examples of suitable slurries for use with the pad of the present invention, include but are not limited to the slurries disclosed in U.S. Patent No. 6,656,241 and U.S. Patent Application No. 09/882, 549, which published as publication number 2003/0094593. In a non-limiting embodiment, the polishing slurry can be interposed between the first layer 12 of the pad 10 and the substrate to be polished. The polishing or planarizing process can include moving the polishing pad 10 relative to the substrate being polished. A variety of polishing slurries or slurries are known in the art. Non-limiting examples of suitable slurries for use in the present invention include slurries comprising abrasive

particles. Abrasives that can be used in the slurries include particulate cerium oxide, particulate alumina, particulate silica and the like. Examples of commercial slurries for use in the polishing of semiconductor substrates include but are not limited to ILD1200 and ILD1300 available from Rodel, Inc. Newark Del. and Semi-Sperse AM100 and Semi-Sperse 12 available from Cabot Microelectronics Materials Division, Aurora, Ill.

**[0083]** In a non-limiting embodiment, the polishing pad 10 of the present invention can be utilized with an apparatus for planarizing an article having a non-planar surface. The planarizing apparatus can include a retaining means for holding the article; and a motive power means for moving the pad 10 and the retaining means with respect to the other such that movement of the pad 10 and the retaining means causes the slurry and the planarizing surface 18 of the pad 10 to contact and planarize the non-planar surface of the article. In a further non-limiting embodiment, the planarizing apparatus can include a means of renewing the polishing or planarizing surface of the pad 10. A non-limiting example of a suitable renewing means includes a mechanical arm equipped with an abrasive disk which abrades the work surface 18 of the pad 10.

**[0084]** In an alternate non-limiting embodiment, the planarizing apparatus can include an apparatus 34 for conducting in-situ metrology of the article being polished or planarized. Commercial polishing or planarizing apparatuses are available from equipment manufacturers such as Applied Materials, LAM Research, SpeedFam-IPEC, and Ebara Corp.

**[0085]** In a non-limiting embodiment, the pad 10 of the present invention can be placed on a cylindrical metal base; and can be connected to at least a portion of the base with a layer of adhesive. Suitable adhesives can include a wide variety of known adhesives. In a further non-limiting example, the pad 10 can be placed on the cylindrical metal base or platen 24 of a polishing or planarizing apparatus that includes a means 34 of conducting in-situ metrology of the article being polished. The pad 10 can be placed such that its window 32 can be aligned with the metrology window 34 of the platen 24.

#### **EXAMPLE 1**

**[0086]** A polishing pad 10 with a window 32 was prepared as follows:

**[0087]** 1. A first layer 12 was prepared according to Recipe A described below.

**[0088]** 2. A 1/2" X 2" rectangular hole 28 was cut into the first layer 12 using a straight-edge and a scalpel-style utility knife.

**[0089]** 3. A second layer 26 was formed using High Performance Double Coated Tape 9500PC, commercially obtained from 3M Industrial Tape and Specialties Division. The adhesive layer of the tape was adhered to the bottom side of the first layer 12 such that the rectangular opening 28 in the first layer 12 was substantially spanned by the tape.

**[0090]** 4. A third layer 14 was formed using a 0.060" thick sheet of polyurethane foam, having trade name PORON 4701-50, commercially obtained from Rogers Corporation. A 1/2" X 2" rectangular hole 30 was cut into the third layer 14 using a straight-edge and a scalpel-style utility knife.

**[0091]** 5. The third layer 14 was adhered to the second layer 26 by removing the release paper from the second layer 26 and applying the third layer 14 to the adhesive film thus exposed. The third layer 14 was positioned such that the rectangular openings 28 and 30 in the first layer 12 and the third layer 14 were substantially aligned.

**[0092]** 6. The three-layer stack assembly (pad 10) was then pressed together and passed through a calendar roll set.

**[0093]** 7. A window 32 was formed by removing a portion of the adhesive on the upper and lower sides of the second layer 26. The adhesive was removed by contacting it with a 1/2" X 2" rectangular piece of Teslin® SP-1000, commercially available from PPG Industries, Incorporated, pressing the piece by hand to ensure good contact between the adhesive and the Teslin® SP-1000, then peeling away the Teslin® SP-1000. The adhesive selectively adhered to the Teslin® SP-1000, leaving the substantially clear film of the window 32 free of adhesive.

**[0094]** The resulting pad 10 stack had a rectangular window 32 having a size of 1/2" X 2".

**[0095]** Recipe A for Pad 10 First Layer 14:

[0096] Step 1

[0097] Particulate crosslinked polyurethane was prepared using the ingredients listed in Table A.

TABLE A

Ingredients	Weight (grams)
Charge 1	
diamine curative (a)	810
surfactant (b)	30.6
methyl isobutyl ketone solvent	822
Charge 2	
isocyanate functional prepolymer (c)	2112

Wherein (a) may be LONZACURE MCDEA diamine curative obtained from Air Products and Chemicals, Inc, which describes it as methylene bis(chlorodiethylaniline); (b) may be PLURONIC F108 surfactant, obtained from BASF Corporation; and (c) may be ARITHANE PHP-75D prepolymer, obtained from Air Products and Chemicals, Inc, which describes it as the isocyanate functional reaction product of toluene diisocyanate and poly(tetramethylene glycol).

[0098] Charge 1 was added to an open container and warmed with stirring on a hot plate until the contents of the container reached a temperature of 35° C. Stirring was continued at this temperature until the ingredients formed a substantially homogeneous solution. The container was then removed from the hot plate. Charge 2 was warmed to a temperature of 55° C. using a water bath then added to Charge 1. The contents were mixed for a period of three (3) minutes with a motor driven impeller until uniform. The contents of the container were then quickly poured into 10 kilograms of deionized water at a temperature of 40° C., with concurrent vigorous stirring of the deionized water. Upon



completion of the addition of the contents of the container, vigorous mixing of the deionized water was continued for an additional 60 minutes. The wet particulate crosslinked polyurethane was classified using a stack of two sieves. The top sieve had a mesh size of 50 mesh (300 micron sieve openings), and the bottom sieve had a mesh size of 140 mesh (105 micron sieve openings). The isolated particulate crosslinked polyurethane from the 140 mesh was dried overnight in an oven at a temperature of 80° C.

**[0099]** Step 2:

**[0100]** A polishing pad 10 comprising particulate crosslinked polyurethane and crosslinked polyurethane binder was prepared using the ingredients summarized in the following Table B.

TABLE B

Ingredients	Weight (grams)
	Charge 1
particulate crosslinked polyurethane	
of step 1	918
	Charge 2
isocyanate functional prepolymer (c)	265
aliphatic polyisocyanate (d)	8.5
additive (e)	8.5 acetone solvent 62

Wherein (c) is described above; (d) may be DESMODUR N 3300 aliphatic polyisocyanate, obtained from Bayer Corporation, Coatings and Colorants Division, which describes it as a polyfunctional aliphatic isocyanate resin based on hexamethylene

diisocyanate; (e) may be Lanco PP1362D micronized modified polypropylene wax, obtained from The Lubrizol Corporation.

**[0101]** Charge 2 was mixed until substantially homogeneous, using a motor driven stainless steel impeller. The substantially homogenous mixture of Charge 2 was then combined with Charge 1 in a suitable container and mixed together by means of a motor driven mixer. A 1040 gram portion of the combination of Charges 1 and 2 was then introduced onto a 26".times.26" flat mold. The mold was fed through a pair of rollers at ambient temperature to form a sheet that was 0.100" thick. The sheet was cured at a temperature of 25° C. and 80% relative humidity for 18 hours, followed by a temperature of 130° C. for 1 hour. Circular pad layers 12 with a 22.5" diameter were cut from the sheet then the upper and lower surfaces of the pad layer 12 were made parallel using a milling machine.

**[0102]** The resulting pad layer 12 was used as the first layer 12 in Example 1.